CLASSROOM ACOUSTICS FOR ACCEPTABLE SPEECH RECOGNITION: A REVIEW

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Introduction

One might think that the basic acoustical requirements for classrooms are well established. The fact that communication problems are frequently encountered and the current flourish of new work on this topic indicates that problems remain to be solved. As Fig. 1 illustrates, speech intelligibility scores increase with increasing speech signal-to-noise ratio (S/N) until near 100% intelligibility is reached. Thus good conditions for speech are a question of obtaining adequate S/N ratios. However, one must appreciate what contributes to 'effective' speech and noise levels.

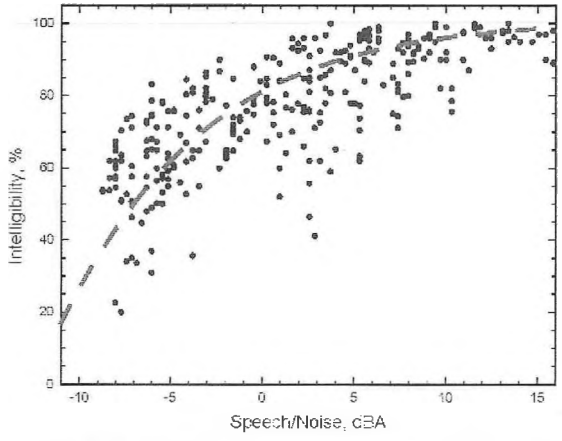

Fig. 1. Intelligibility vs. speech signal-to-noise ratio[1].

Components of Effective Speech Levels

The 'effective' speech level is that due to the combination of the direct sound and early arriving reflections of the speech sound that together contribute to increasing intelligibility. The noise is the combination of ambient noise in the room plus reverberant speech sounds that together decrease intelligibility. This effective speech/noise ratio was termed a useful/detrimental (U/D) sound ratio by Lochner and Burger [2] and intelligibility scores are well related to U/D values as seen in Fig. 2.

In spite of extensive early work, many research studies have shown no appreciation of the different effects of early and late-arriving reflections of speech sounds. Some have even questioned the importance of early reflections. New results, shown in Fig. 3 confirm that early reflection energy has approximately the same benefit as increased direct sound energy for improving speech intelligibility scores and that this holds true for listeners with hearing impairment too. Further analyses have demonstrated that early reflection energy can increase effective speech levels in rooms by as much as 9 dB. In some situations, such as when the talker turns their head or for listeners at the rear of a room, early reflection energy is critical to understanding speech.

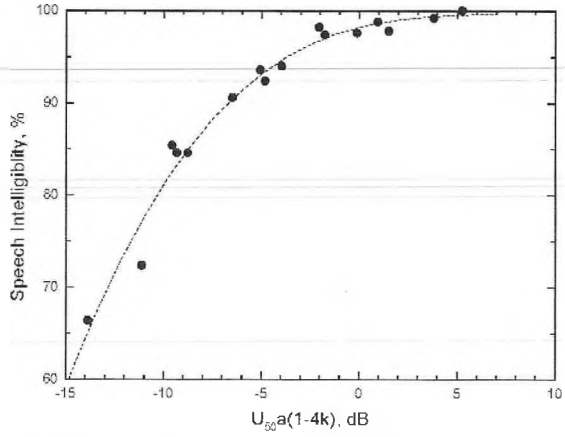

Fig. 2. Intelligibility vs. useful/detrimental ratio for 1 to 4 kHz results. [3].

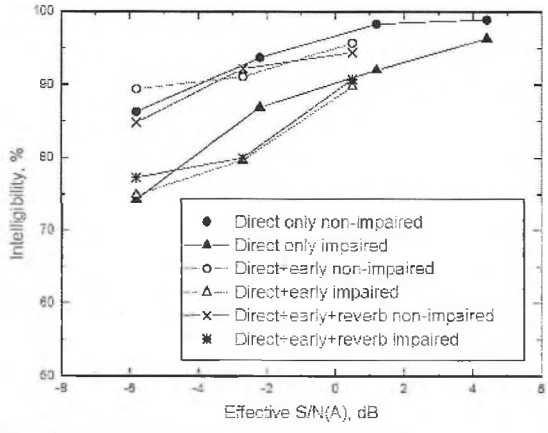

Fig. 3. Demonstration of the benefit of early reflections [4].

Measuring Speech and Noise Levels

Almost all reported measurements of noise levels in classrooms suggest that noise levels are too high for optimum speech communication. Fig. 4 summarizes measured noise levels from various studies. These vary from 40 to over 80 dBA and show a trend to be greater for classes of younger children. It is not always clear how such measurements were made and in some cases these ambient levels may also include some student activity noise. Similarly, there is some uncertainty as to the level of speech sounds produced by typical teachers. To resolve the need for more representative measurements of speech and noise levels, Hodgson et al. [6] proposed deriving them from statistical distributions of recorded speech and noise levels in classrooms. Fig. 5 shows an example of this technique for a male high school teacher using an overhead projector. The peaks due to the teacher's voice level and

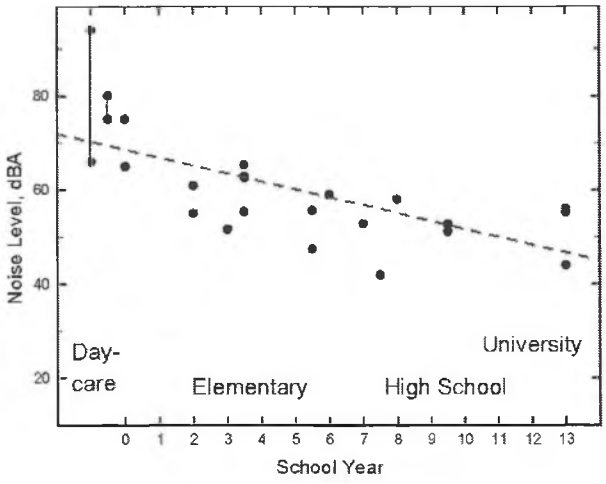

Fig 4. Reported classroom noise levels[5].

the projector are clearly identified. Preliminary measurements of this type suggest that teacher's voice levels are louder than often assumed.

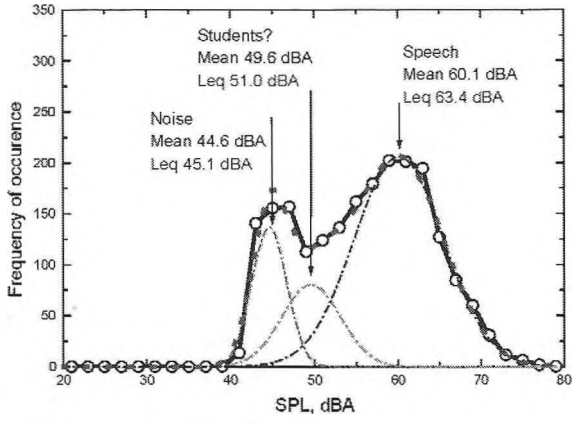

Fig. 5. Statistical distribution of speech and noise levels.

Room Acoustics Criteria for Classrooms

Near-optimum conditions for speech communication in school classrooms are often said to require noise levels to be no more than 35 dBA and an optimum reverberation time (RT) of about 0.5 s [7,8]. The derivation of such criteria are based on assumed speech source levels and typical ambient noise levels. There is also a trade-off between optimum reverberation time and the maximum acceptable ambient noise level as illustrated by the equal U/D contours in Fig. 6. These indicate that in noisier conditions a slightly higher reverberation time would be optimum. This is due to the relation between increased early reflections and RT. (Of course, too much reverberation adds unwanted later arriving speech sounds). It is also known that younger children and other special groups need better conditions than young adults to achieve the same intelligibility scores. Estimates of the required maximum noise levels as a function of the age of younger listeners can lead to very low noise level requirements [5] that seem contrary to common experience.

However, if the assumed teacher voice level is incorrect and if teachers tend to use a stronger voice level, the background noise level requirements could be 5 or 10 dBA higher. Recent measurements indicate that teacher's voice levels correspond to about 65 dBA (at 1 m) rather than the 55 dBA assumed in deriving the 35 dBA maximum noise level criteria. There is also the question of the maximum voice level that teachers should use to avoid any voice impairment that is a common problem among many teachers [5].

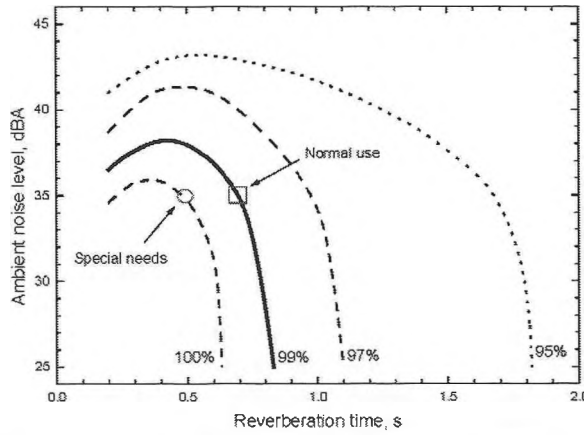

Fig. 6. Equal U/D contours by noise level and RT[7].

Conclusions

Although the basic principles seem well established, there is still considerable uncertainty in current derivations of acoustical criteria for classrooms. We need to better define safe teacher voice levels and the required speech/noise ratios for all ages of children. We also need to develop procedures for designing rooms that maximize the benefits of early-reflected speech sounds. A new project, part of the Canadian Language and Literacy Research network, will attempt to answer some of these questions.

References

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